

RD-A129 749

EVALUATION OF BURIED-CABLE DETERIORATION AT GUAM
MARIANA ISLANDS(U) NAVAL RESEARCH LAB WASHINGTON DC
W M MCDAVIT 13 JUN 83 NRL-8717

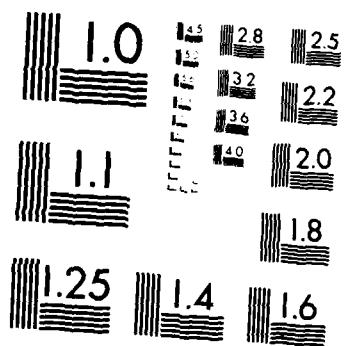
1/1

UNCLASSIFIED

F/G 11/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

ADA 129749

(2)
NRL Report 8717

Evaluation of Buried-Cable Deterioration at Guam, Mariana Islands

WILLIAM M. MCDAVIT

*Terrestrial Systems Branch
Space Systems Division*

June 13, 1983



NAVAL RESEARCH LABORATORY
Washington, D.C.

Approved for public release; distribution unlimited.

DTIC
ELECTE
JUN 24 1983
S D
E

DTIC FILE COPY

83 06 28 09

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM												
1. REPORT NUMBER NRL Report 8717	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER												
4. TITLE (and Subtitle) EVALUATION OF BURIED-CABLE DETERIORATION AT GUAM, MARIANA ISLANDS	5. TYPE OF REPORT & PERIOD COVERED Final report													
	6. PERFORMING ORG. REPORT NUMBER													
7. AUTHOR(s) William M. McDavit	8. CONTRACT OR GRANT NUMBER(s)													
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, DC 20375	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 77-G126-E3													
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217	12. REPORT DATE June 13, 1983													
	13. NUMBER OF PAGES 9													
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED													
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE													
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.														
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)														
18. SUPPLEMENTARY NOTES														
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)														
<table border="0"> <tr> <td>Termites</td> <td>Four-wire no. 14 AWG</td> <td>Copper-wire corrosion</td> </tr> <tr> <td>NAVCAMS</td> <td>Direct burial</td> <td>Guam, Mariana Islands</td> </tr> <tr> <td>Saltwater</td> <td>Silicon-controlled rectifier</td> <td></td> </tr> <tr> <td>Green powder</td> <td>Deteriorating insulation</td> <td></td> </tr> </table>			Termites	Four-wire no. 14 AWG	Copper-wire corrosion	NAVCAMS	Direct burial	Guam, Mariana Islands	Saltwater	Silicon-controlled rectifier		Green powder	Deteriorating insulation	
Termites	Four-wire no. 14 AWG	Copper-wire corrosion												
NAVCAMS	Direct burial	Guam, Mariana Islands												
Saltwater	Silicon-controlled rectifier													
Green powder	Deteriorating insulation													
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)														
<p>Sporadic breaks were occurring in buried, neoprene-jacketed, four-wire no.-14 AWG cables at the U.S. Naval Communications Area Master Station (NAVCAMS), Guam, M.I. These cables conveyed the safety-interlock signals to three operational antennas. It was determined that the probable cause of these breaks was seawater contact with the copper conductors and subsequent corrosion. How the sporadic contamination occurred could not be determined.</p>														

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

INTRODUCTION	1
OBSERVATIONS	2
CONCLUSIONS	4
ACKNOWLEDGMENTS	5
APPENDIX — Chemical Analysis and Causes of Corrosion of the Cables	6

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	



EVALUATION OF BURIED-CABLE DETERIORATION AT GUAM, MARIANA ISLANDS

INTRODUCTION

During the autumn of 1975 a sophisticated electronic collection system was installed by Naval Research Laboratory (NRL) Space system Division (SSD) personnel at the Naval Communications Area Master Station (NAVCAMS), Guam, Mariana Islands. This installation included three receiving antennas, displaced approximately 250 m from the system's Operations Building (Fig. 1). All cabling to these antennas from the operations area was buried, with both physical and environmental protection (sand bed, steel covers, and chlordane treatment). These cables met or exceeded commercial and military direct-burial specifications (MIL-C-915). One particular group of conductors, required for each antenna, conveyed the silicon-controlled rectifier (SCR) amplifier power and safety-interlock voltages to the antenna-pedestal drive mechanisms. These conductors (in compliance with MIL-C-915 specifications), of standard 76-m and 152-m lengths, were spliced, and the splices were encapsulated in epoxy prior to burial (Fig. 2). Four of these conductors, as shown in Fig. 2, were configured in a neoprene-jacketed, four-conductor, No.-14 AWG cable, and this cable is the topic of this report. All other buried cables and conductors are of little significance to this report.

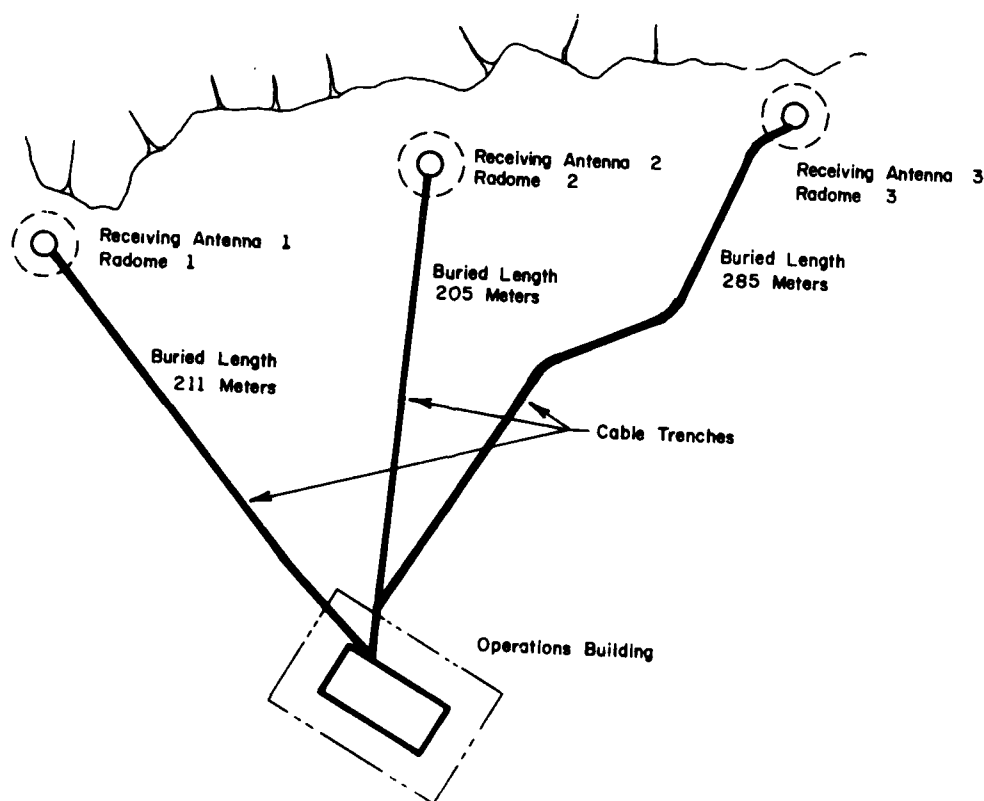


Fig. 1 - Guam operations site

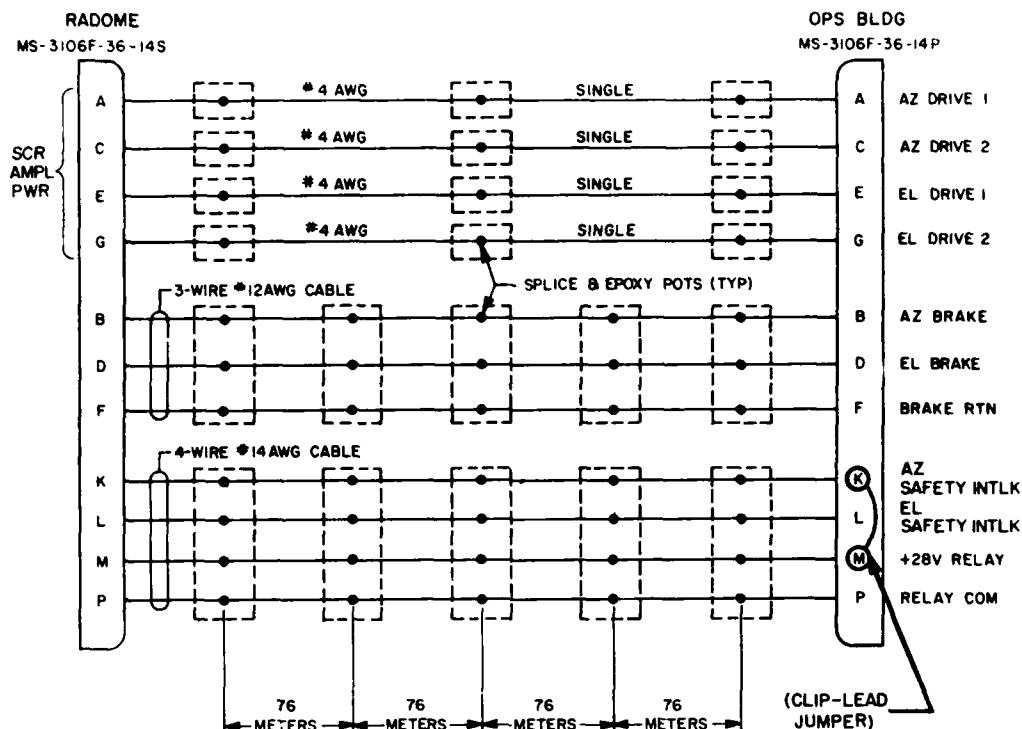


Fig. 2 — Cables in Fig. 1, including the four-wire cable of concern in this report

In April 1980 NAVCAMS issued a "Problem Reporting and Enhancement Recommendation" (PRAER) message, relating to a break in one of the buried SCR conductors (Fig. 3). This unusual situation opened a safety-interlock circuit and negated the use of one operational antenna. By electronic means, site maintenance personnel located the break, which was in the red-insulated wire. The trench was excavated at that point, and the safety-interlock conductor with the red insulation was repaired by splicing. During this endeavor, site personnel noted evidence of termite activity and postulated that the damage was caused by termites. One month later the author was on-site at NAVCAMS and conducted a spot inspection in the other two antenna cable trenches. In all cases evidence of termites having been present was substantiated. No evidence of external damage to the insulations of the cables/wires could be observed. Within the next 3 months breaks occurred in the other two trenches in the red wires, adversely affecting the other two operational antennas. Thereupon station maintenance personnel installed a clip-lead jumper bypassing the safety interlock, to return the antennas to a workable status (Fig. 2).

Naval Research Laboratory SSD personnel were then tasked to (A) supervise the excavation of all of the Guam cable trenches, (B) install and verify operation of new SCR cables, and (C) determine the cause of the cable failure. In April 1980, a two-man SSD team proceeded to Guam to undertake these assignments. These tasks were completed, and this report will be directed at task C, the evaluation of observations and the determination of the cause(s) for the cable breaks.

OBSERVATIONS

A thorough meter-by-meter visual examination of the outer insulations of all cables/wires in the trenches was conducted to determine if environmental, chemical, animal, or insect influences had caused the wire breaks and subsequent deterioration. No evidence of such causes was seen. Close

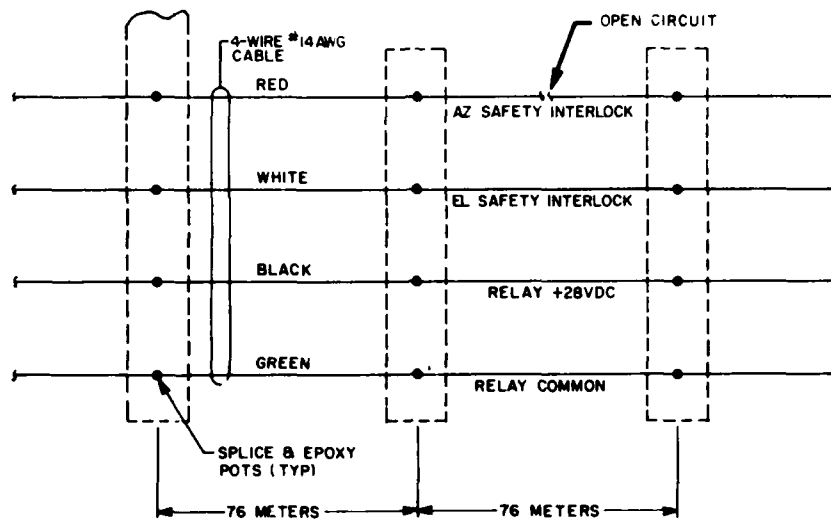


Fig. 3 — Break that occurred in the four-wire cable. A break occurred in the wire with red insulation in each of the three trenches, with one break being fixed by excavation and splicing and the other two being made workable by a jumper as shown in Fig. 2.

visual scrutiny of the outer insulations revealed no breaks or obvious deterioration. This finding was interesting, in that shifting coral terrain is commonplace on Guam. Definitive evidence of termite activity was constant throughout the search, but termite-inflicted damage was not found.

Attention was then given specifically to the four-wire, No.-14 AWG cable in question. All of this cable type had been removed from the trenches. A thorough physical examination of these external surfaces revealed no visible damage

Next approximately 15 m of the defective cable type was carefully stripped of the outer insulation to inspect the four insulated wires inside more effectively and to determine if moisture was present. It was during this phase of the investigation that green spots were noticed on the red-insulation wire. The spots varied in size and color intensity and were not spaced evenly or continuously. There was, however, an apparent correlation between the diameter of the spots and the color intensity; that is, the darker green spots were greater in diameter, and vice versa. By touch, the spotted areas appeared to be some sort of deterioration in the insulation, since scabs could be flaked or picked off. Also noted was a tendency for the spots to be grouped in areas 2 to 4 m long. Investigations into some of the other 76-m sections showed inconsistencies in the spotting effect: some sections had similar spotting, some had none at all, and others had spots of lesser frequency. Continuity checks of various sections proved to be inconclusive overall, although the following findings were validated:

- Wire sections that visibly showed no spotting effect always had low resistivity;
- Some wire sections, exhibiting lesser amounts of spotting intensity and frequency, frequently indicated high resistivity;
- Wire sections that had wide, deeply colored green spots always displayed discontinuity;
- Except for two isolated cases on white-insulation wires, spotting always occurred on the red-insulation wires;
- Of all the cables stripped of their outer insulation, none showed signs of any form of moisture being present.

To try to determine the cause of these deteriorations, some of the spotted areas in the impaired insulations were carefully cut away. In so doing, it was discovered that the copper stranded wire under these spots was corroding and disintegrating. Now it had to be determined whether the corroding wire was causing the spots in the insulation or the spots were causing the copper corrosion.

To determine the cause and effect relationships, samples of the affected cables were shipped to NRL for chemical analysis of the wires by personnel in the Chemistry Division. The results of that study, conducted between September and December 1981, is detailed in the Appendix.

CONCLUSIONS

Seawater salts were found in the stranded copper conductor and were the major contributors to the ultimate destruction of the wire. How the wire was initially exposed to saltwater is not known. If the cable, of which the affected conductor was a part, had been stored or shipped in a saltwater-contaminated environment, then the highest level of contamination would have been concentrated at the ends of the cable, where the conductors were exposed, that is, at the only two points where the direct-burial-qualified outer insulation is nonexistent. On-site visual inspections did not reveal that situation. No evidence of deterioration existed at the ends of any of the 12 sections of buried cables. Similarly, it cannot be logically presumed that the bare copper wire had been stored by the manufacturer in a saltwater environment. Had this happened, corrosion would have been found throughout greater areas of the affected conductors.

Unanswered also is why the salts collected in the wire so sporadically. One improbable postulation is that the insulated wires, prior to being formed into a cable, were stored in a saltwater environment. Since primarily only wires with red insulation were affected, the following would have to be assumed: a different storage area was used for the black, white, and green wires, the red wire had been purchased from a different subcontractor and was contaminated when delivered to the cable manufacturer, and *while being stored in a saltwater environment, the red wire absorbed salts through pinhole defects in the insulation.* Suppositions of this nature are unending.

It was reasonable to presume that not all of the 12 76-m sections would be contaminated, since all of them may not have come from the same manufacturing source. This presumption could not be verified, due to the lack of manufacturer's identification on the exterior surfaces. The reason only the wires with red insulation were affected will remain unknown. Chemical analysis has proven the red insulation was not contaminated.

Apparently, the contaminant had been concentrated sporadically in the wire in varying degrees of intensity, accounting for some points having greater resistivity than others. The points of greatest resistivity were the first to break down. The higher the resistivity, the greater the temperature rise with electrical current flow and consequently the faster the rate of corrosion. Eventually the total effect was catastrophic, with the conductor breaking at the point that had the greatest level of contaminant. The process took 5 years to manifest itself in the first case and slightly longer in the other two cases. It can be assumed that other breaks at points of high contamination would have followed.

To assert that the sequence of occurrences was antenna related is unreasonable. All three antennas use a separate but identical *safe/run* safety-interlock circuit. These circuits are normally in an active (*run*) condition, and current flow is realized when the antennas are in a *run* state. This condition had prevailed approximately 90% of the time for all three antennas.

Analysis findings in Appendix A disclose that the contaminants were found in the copper conductors and not in the wire insulations: hence the charred and flaking spots on the insulation were not a cause of the problem but an effect. Since the affected cable has a federal stock number (FSN) and can be manufactured by many commercial companies, it is impossible to identify the original supplier of the defective cables or identify a specific production run.

The cable type referenced (FSN-6145-073-3700) is frequently used within the federal government. For those governmental agencies having their own GSA supplies, this cable type is often an on-the-shelf item. Electricians regularly use it when tasks call for direct-burial applications. Since it is a popular cable type, it would seem highly unlikely that a recommendation of removal from the federal supply system would be prudent. Similarly, it would not be cost effective to recommend a chemical analysis of all lengths of this cable in GSA supply areas.

Finally, after all other alternatives have been considered, there is only one logical course of action: make this report available to all supply officers in the U.S. Government, with the intention of warning potential users of the possible consequences involved.

ACKNOWLEDGMENTS

The following individuals contributed to the accomplishments of the task and the ensuing reported conclusions: Paul R. Tillery, Clingman E. Emerson, John C. Cooper, Robert G. Bryant, and Janice L. Wilson. Also contributing were the U.S. Naval Station, Public Works Center, Maintenance and Transportation Departments, Guam, Mariana Islands, and the U.S. Naval Communications Area Master Station WESTPAC, Naval Security Group Department, Division 21, Guam, Mariana Islands.

Appendix

CHEMICAL ANALYSIS AND CAUSES OF CORROSION OF THE CABLES

In September 1981, samples of cable from a Guam transmitter facility were provided to NRL Code 6133 with a request for diagnosis of localized corrosion and electrical failure. This appendix describes chemical analyses performed, the data obtained, and the conclusion that electrical continuity was most likely broken as a result of seawater contact with the copper conductor and subsequent corrosion.

The samples consisted of about 6 m of four-conductor cable, with each conductor covered with neoprene or similar insulating material and the four insulated conductors covered with an outer sheath of heavy neoprene. Each stranded copper conductor showed considerable surface oxidation throughout the portions of the sample. In a few spots with diameters of 1 to 5 cm, in one separate small piece of cable and near one end of the single long piece of cable, the copper conductor covered with red insulation had disintegrated into a greenish powder. In most of the ten or so spots where this disintegration occurred, there was evidence of damage to the insulation covering the stranded copper conductor. The insulation had bubbled and charred from the inside out. There was no evidence of damage to the outer neoprene sheath. In use these cables are located in a well-protected buried channel about 140 m above sea level.

CHEMICAL ANALYSIS AND SPECTRAL RESULTS

DC Argon Plasma Emission Spectroscopy (DCP) analyses* were performed on weighted, dissolved samples of the green powder (Table A1). The results showed the bulk of the material to be a copper salt (46% copper) with significant amounts of phosphorous, boron, iron, zinc, magnesium, calcium, and other trace elements. A chloride analysis of the green powder showed it to consist of 32% chloride by weight. The additional 22% is composed of oxides, carbonates, sulfates, phosphates, and other anions.

Qualitative x-ray fluorescence analyses were performed on various portions of the cable and insulation to aid in determining the corrosion cause. The results are summarized in Table A2. In addition to confirming copper and chloride as major constituents of the green material, these results showed substantial amounts of sulfur, zinc, and calcium in the green powder and no chlorine present in the insulation.

Infrared spectra were similar for the green powder and for $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$, although the likely exchange of chloride with bromide in the potassium bromide matrix used would minimize the usefulness of these results. Insufficient material remained to permit further analyses by other methods.

The initial results of trace analysis (Table A1) with the presence of large amounts of chloride in the green powder provided two working hypotheses: either saltwater corrosion of the copper wire had occurred during the history of the cable or ingredients in the insulating material (such as traces of hydrochloric acid, vinyl chloride, or other reactive chlorides) used during manufacturing had corroded

*K. Smidt, Rm. Panayappan, and J.C. Cooper, "Determination of Detection Limits by DC Argon Plasma Emission Spectrometry," NRL Memorandum Report 4583, July 15, 1981.

Table A1 — DCP Analysis
of the Green Powder

Element*	Content (wt-%)
B	0.01
P	0.2
Cd	0.01
Fe	0.1
Zn	0.3
Cu	46
Mg	0.007
Pb	0.007
Ca	0.2
Co	0.003
Al	0.05
Ba	0.03
Cr	0.003

*In addition, qualitative results show substantial amounts of sodium present.

Table A2 — X-Ray Fluorescence Analysis (Qualitative)

Sample	Elements in Significant Amounts				
	Ca	Cu	Zn	Cl	S
Mylar blank	--	--	--	--	--
Green powder	✓	✓	✓	✓	✓
Black "oxide" coating on the wire	✓	✓	✓	--	--
Outside of the red insulation	✓	--	✓	--	--

the copper wire. Either possibility would lead to nonuniform corrosion of the copper, resulting in localized resistive heating and subsequent faster corrosion at the initial corrosion sites. Failure to find chlorine in the bulk of the insulating material rules out the second hypothesis.

The presence of other seawater constituents such as sulfur (probably sulfate), phosphorous (probably phosphates), calcium, and magnesium lends considerable support to the first hypothesis even though the amounts present are not in exactly the same proportions as in seawater. In addition, the presence of considerable oxidation of copper to copper (II) oxide, determined by visual inspection and its rapid dissolution in hydrochloric acid, throughout the cable length suggests failure of insulation integrity, at least to passage of air and moisture. No obvious breaks in the outer neoprene covering of the cable were found. However, seawater aerosol permeation of a nonairtight covering is possible even in a semiprotected environment about 140 m above sea level. The small pinhole and larger ruptures of the inner insulation appear to result from localized heating due to higher conductor resistance at the corrosion sites. They occur from the inside of the insulation outward and show considerable evidence of heat charring.

Insufficient quantities of cable with greenish material precluded more detailed speciation, and manufacturing-source ambiguities inherent in the Navy supply system made tracing of the manufacturing methods impossible. It is reasonably certain, however, that saltwater-induced corrosion of the copper conductors was the major cause of failure of these cables.

END

FILMED

7-83

DTIC